Macroeconomic Conceptualization in *EVE Online*

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1. Introduction:

Scarcity is the central underpinning within the study of economics. Although bits of data within a digital platform are not themselves scarce, the content produced using these bits within a virtual reality is "one of the few naturally scarce resources in a virtual economy" (Lehdonvirta and Castronova, 2014, p. 10).[1] Content within a virtual economy includes any digital thing within the world that is collectable and consumable by a user. In general, it is possible to divide virtual platforms into two sorts: those which do not allow user to user trading of content and those which permit such activity. Since voluntary trade is a necessary component in the creation of any economy, the most fruitful research focuses on the latter kind of virtual platforms with specific reference to the virtual realities of Massive Multiplayer Online Role-Playing Games (MMORPGs).[2] Having both of these features of scarcity and voluntary trade, the virtual realities of MMORPGs may serve as a valuable laboratory for the study of real-world economics questions. This paper explores this potential of MMORPGs for macroeconomic research by reviewing previous claims made regarding the prevalence of the quantity theory of money within virtual economies and by testing general predictions of the gravity model of trade within the virtual universe. The specific MMORPG of study in this work is *EVE Online*. I propose further research of MMORPGs either through the creation of a virtual world by macroeconomists or through cooperation for data-sharing with existing platform developers.

Existing MMORPGs provide an ideal testing ground for theoretical frameworks because not only do they feature much of the same institutions as real-world economies, but they also allow for better data collection than what is available in the real world. Within MMORPGs, players, or

[1] The other two scarcities being computing resources and user attention.
[2] In these video games, a user is able to create a virtual avatar in an open online world where the user can collect and interact with in game content with a large number of other players. An example is *EverQuest II.*

even guilds, trade goods and services amongst themselves with in-game currency through individual transactions, or, more commonly, through organized markets.[3] One such example is the "Auction House" within *World of Warcraft* (WOW). The auction allows players to see real time information regarding the prices of items and allows players to make asks and bids accordingly. What is even more spectacular about MMORPGs is the amount of information that is player generated and posted publicly on websites. In WOW, a popular resource is *The Undermine Journal*, which has real time information on prices and volumes which allows for better decision making within the marketplace. Such data collection can be done with census-like precision, instead of relying on samples, since all transactions are recorded by the game and are then data-mined by players to create summaries on items and trends.

Moreover, the opportunity for experimentation does not go unnoticed by the developers of such platforms who either openly or silently conduct behavioral experiments within the game. One such example of a keen content creator is Valve Corp.'s Gabe Newell. During a WTIA[4] conference back in 2011, Newell revealed how Valve Corp "conducts behind-the-scenes pricing experiments" on players' purchasing behavior (Bishop, 2011). Newell explained how Valve tested the price elasticity of certain products within *Team Fortress 2* by changing, unannounced, the USD prices of certain items that could be bought from the company and recorded the information in real time through their selling platform, *Steam*. Newell and his team saw variation across items purchased throughout their price-changing experiment. Changing the virtual world is a relatively easy task for the content creators, which makes virtual worlds the embodiment of the imaginary scenarios which economists dream of for testing theories but do not have the ability to create themselves.

[3] All MMORPGs also feature the ability for player to player bartering, but as in the real world the scale of such transactions is negligible.
[4] Washington Technology Industry Association.

Although I could not conduct macroeconomic experiments over the course of my research, I was instead able to employ publicly available information gathered from *EVE Online*, a sort of space-pirate themed MMORPG which has been around for nearly seventeen years. This game has been studied before by different researchers, such as Tuukka Lehtiniemi, who created and outlined several aggregate macroeconomic indicators that can be observed within the *EVE* universe (2008). CCP Games[5] *EVE Online* makes for an excellent virtual reality to study macroeconomics within because of the game's emphasis on player to player trade and it's the high degree of interactivity between the developer and its user base. Most importantly, player-owned corporations feature prominently within the game[6] and largely function in the same way that real-world corporations would (Rosette, 2007). These agents conduct business in a universe which consists of deliberately inefficient[7] and regionally segmented markets for virtual commodities. Thus, players and corporations are incentivized to take advantage of the resulting arbitrage in constant competition with one another. This virtual environment's similarity to the real world in terms of incentive structure further cements *EVE Online*'s usefulness as a model for the real world.

The first task of this paper is the reevaluation of the conclusion reached previously concerning the effects of money on prices in virtual economies. An important finding in earlier work, "As real as real? Macroeconomic Behavior in a Large-Scale Virtual World" (Castronova et al., 2009) tested several hypotheses related to general macroeconomic theories, such as the quantity theory of money, using a large dataset of information from *EverQuest II* which was made available to the researchers by Sony. This study, which featured four months of data and 314

[5] Crowd Control Productions (CCP) is the publisher of *EVE Online*.
[6] In some sense, it is a de facto goal for players within *EVE* to join or even create a corporation.
[7] In video games, and other virtual economies, players generate wealth as an end of itself unlike in the real world where most people attain wealth as a means to something else. Creating an efficient economy would take away the fun of the player to player trade aspect of an MMORPG. See (Lehdonvirta, and Castronova 2014, p. 6-7) and (Lehdonvirta, and Castronova 2014, p. 263-264) for further information.

million transactions therein, found that price level within the economy moved in the same direction as the money supply and that population increase had a negative effect on price level. Fortunately, CCP Games reports universe-wide economic data for *EVE Online* that includes: the money supply on any given day, the monthly change in CPI, and the nominal output of each good within the CPI basket on a monthly basis. A dataset was created spanning six years of gameplay from 2012 to March 2020. The effects of money supply on nominal output and on price level as given by the change in CPI was subsequently measured to compare with previous findings.

The results of regressing money supply on prices and nominal output suggests that the fluctuations within the aggregate economy of *EVE Online* can be described as that of a real business cycle which experiences frequent technology shocks. Within the game, a one percent increase in the money supply was found to be associated with around a 1.25% increase in nominal output and an overall 0.19% decrease in prices, on average. I believe that the contradictory effect, in relation to the quantity theory of money, of money supply on overall price level stems from the lack of a financial sector or central bank within *EVE Online* in conjunction with the constant expansions made to the game which usually expand the productive capabilities of both players and corporations. Due to the nature of content creation within the game, *EVE Online* essentially plays out a unique scenario outlined by the neo-classical business cycle theory.

This paper then goes on to use the information provided about regional trade within the EVE universe to see if the virtual world also reflects the predictions made by the simplest form of the gravity model of trade. One of the generalizations that the gravity model of trade implies is that the smallest economies are the most open to trade (Anderson, 2011). Regional net exports and output from 64 regions over the course of 46 months is used to examine this prediction with respect to two main frictions, distance and borders. The latter of these frictions is examined by observing

the extant pattern of trade with respect to a measure of regional security which also brings about a discussion of the positive effects of property rights on trade.

I find that interregional trade within *EVE Online* can be modeled, at least in part, by the gravity model of trade and that the game's measure of security appears to be a more important friction than distance. In lieu of bilateral regional trade information, I examined the model with respect to the center of the game's universe, which is the approximate location of the largest trading hub in the *EVE* universe. The regression results suggest that increase in a region's level of production is associated with a decrease in the measure of regional openness as calculated for the study. Furthermore, the distances between a region and the center of the virtual world was an insignificant predictor of regional openness when the average security status of a region was accounted for. Within the section on the gravity model I explain in larger detail why the security measure replicates the real life observed effects of borders on international trade.

The ultimate goal of this research is to advance the study of MMORPGs. These virtual worlds are a great petri dish for testing models because they make it possible to observe hypothetical situations that would otherwise be extremely difficult or impossible to create. Counterfactual what-ifs are important for the validation of models, but they are usually left as a thought experiment. MMORPGs play out these what-ifs, with near perfect data collection, and can therefore provide a review of the theoretical groundwork behind many of our commonly held beliefs on the interactions between macroeconomic indicators.

2. General Design of Virtual Economies

The money of virtual economies of MMORPGs does not flow in the traditional cyclical model that macroeconomics is accustomed to dealing with. While money flows from firms to

households and then back to firms from households in the real-world circular flow model (Mankiw, 2009), in MMORPGs there is a pipes design that functions in a somewhat similar way. A rough outline of the model is shown in figure 2.1. In the pipes model, virtual goods and virtual currency flow top down from faucets to players and then eventually to sinks. Faucets are those interactions within the game which produce digital goods or currency as a result of player actions. In *EVE Online*, mining a material at an asteroid produces a copy of the ore available at the asteroid. With this action, wealth is brought into the game in the form of the ore. From this faucet, the digital good produced can bounce around from player to player until it is ultimately consumed by a sink, which is an interaction which destroys the virtual good or currency, from the game. If the same ore mined at the asteroid is sold to an NPC[8] merchant for virtual currency, then the ore has been

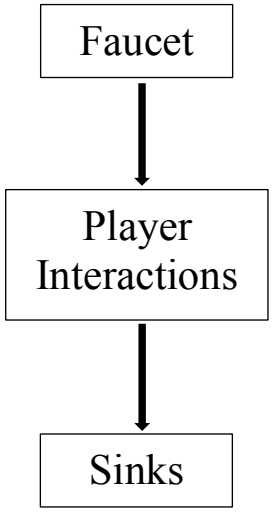

Figure 2.1: The Pipes Model of Goods and Currency Flow

[8] Non-Playable Character. This is a character which is part of the game which players can interact with but cannot play as themselves. These are a sort of stand in for the developers and usually serve as a resource of last resort to the player. Businesses and financial institutions in the U.S. can rely on the federal reserve to step in to act with either new loans or open market operations. In a similar fashion, if a player cannot sell a good in the marketplace for any reason they can always sell it at the (either fixed or dynamic) price floor set by the developers in the form of the price at which NPCs buy that item from the player. Selling to NPCs, then, is essentially the same as selling back to the publisher.

consumed by a goods sink and is removed from the digital world while the currency equivalent[9] of that good is created by the NPC faucet and added to the game's universe.

Most goods do not travel through the digital space in the same way as the example ore and the fact is that most in game interactions between players can have virtual goods and currency trading hands for quite a while before the copy of the good is removed by a sink. A summary of different faucets and sinks as outlined by Lehdonvirta and Castronova, is replicated in table 2.1. As mentioned previously, *Eve Online* players can form corporations, which are essentially guilds[10]

Table 2.1
Faucets and sinks for virtual goods and currencies*

	Virtual Currency	*Virtual Goods*
Faucets	Drops, incentives, cash shops, users selling goods back to publisher	Drops, incentives, cash shops, virtual shops, transformations
Sinks	Virtual shops, payment for services, transaction taxes, time-based fees, maintenance costs, limited lifetime, property tax	Limited lifetime, deterioration, expending, obsolescence, maintenance cost, limited inventory size, publisher buy-back, recycling, redemption, abandoned accounts, transformations

*taken from Lehdonvirta and Castronova, *Virtual Economies: Design and Analysis* page 212

that can pool together resources for specialized objectives within the game. *EVE Online* has lots of different such guilds which move around much of the trade between the universe's different markets. Within markets, if a player exchanges virtual currency, or in this case, ISK, for a virtual

[9] The currency equivalent in this case would almost certainly be determined by the price floor, as the NPC is the buyer of last resort whenever prices in player run markets fall too low to make it worth certain players' time to collect the associated resource.
[10] Another comparison would be to call them functionally the same as the East India Company.

good, then they are simply circulating money and it is not destroyed. In *EVE* these goods can range from the simple example of the ore to the more valuable commodities such as capital space ships. [11] The vast majority of interactions within MMORPGs involve player to player trading and even institution to institution trade, which means that most resources created within the game circulate for quite a while. To keep goods and currency in circulation goods may deteriorate, become obsolete (as would be the case with an outdated ship), or, most commonly, be destroyed as a result of a space battle.[12] Further explanation of how virtual economies function, as well as what mechanisms of trade and production are available in *EVE* are given in the proceeding sections where necessary.

3. Quantity Theory of Money

3.1. Regulator Objectives, Environment, and Available Tools in MMORPGs

One of the chief concerns of policy makers, and the reason why they study the effects of money supply, is to find the tools with which to stabilize prices within an economy. Developers who oversee MMORPGs that feature organized bourses may also be interested in price stability since they would like to curb inflation as much as possible within a virtual reality that has potentially no end with regards to the creation of wealth (Lehdonvirta, and Castronova, 2014, p. 220-224). *EVE Online* provides a special case in which we can examine and review the relationship between money and prices in the absence of a finance sector, a central bank and the relative lack of government intervention.

[11] The qualifier of capital here is similar to naval jargon. Capital ships would be something like a space battleship.
[12] The infamous "Bloodbath of B-R5RB" was possibly the largest player-versus-player event of all time and resulted in the overall loss of somewhere from between $300,000 to $330,000 in ships destroyed.

Like most MMORPGs, *EVE Online* does not have either a player-run nor a developer owned financial system. This would never occur on the part of the players since there is no way to enforce any liability on either the creditor or lender. In *EVE*, there was a notable instance in which one player set up the 'EVE Intergalactic Bank' only to scam other players for the equivalent of around $170,000 worth[13] of ISK (Rosette, 2007). Some small form financing may occur within a corporation[14], where debts can be enforced via social pressures, but it is highly improbable that it would expand into something significant that would resemble anything near a real-world financial system. Similarly, there is no way or reason that a developer would finance their players with an in-game loan since playing the game is voluntary and players can just quit the game any time after creating unnecessary and superfluous funds in the game. Therefore, any discussion of the quantity theory of money or money generation in general within virtual worlds excludes interest rates.

Furthermore, a virtual economy like *EVE Online* does not feature either unemployment or monetary intervention on the part of an economic regulator. For governments and certain central banks, measures of unemployment are a great deal of concern and calls for action in the form of bailouts of or similar stimuli. An MMORPG developer's main worry is a decreasing player count, which is the most analogous comparison to unemployment in the real world. MMORPG publishers are no different from other profit maximizing firms, and in the case of a virtual reality, the more subscribers the better and the longer the firm can survive. Unlike governments or financial institutions, however, developers do not issue a systematic *monetary* plan to help out a certain part

[13] The exploration of the real-world currency pricing of online goods is a topic that would deserve a paper in its own right. Almost all MMORPGs prevent the third-party trading of virtual goods for real world money. This figure was likely calculated using 'black market' price valuations of goods in *EVE* alongside the price in ISK of that good within the game.

[14] Corporations in EVE, like guilds in other MMORPGs or in real life, lowers the risk posed by the more dangerous and rewarding missions that its members may decide to collectively take on. Castronova and Fairfield (2007) describe the sophistication by which a guild can operate based on property rights to loot created by strong social ties. Failed missions can be compensated, often by the more experienced and wealthy players.

of the virtual economy. If the developers of *EVE Online*, were concerned about the lack of players engaging in mining, which is highly tied to the price of ore in the player run markets, the mechanisms by which they would stimulate that aspect of the game would be with the addition of new content[15] or the reform of current content. For instance, to raise the price level of ore and get players mining again, CCP can simply raise the price at which NPCs buy the ore from players or add in new ore that is essential to the production of better final goods, such as a new ship. If the developers do not want to add new content, then they can tighten the ore faucets, potentially raising the price level as a result of the subsequent ore scarcity. Publishers may also decide to intervene in the state of the game in response to demands from their player base (customer demand) as seen in the case of *RuneScape*.[16] Thus, through the creation and adjustment pipes for content, the developers use a sort of subsidy to fix issues related to the underuse or overuse of content that creates unemployment in the economy, where the idea of unemployment is measured with the number of concurrent users or new membership subscriptions per month.

3.2. Quantity Theory sans Finance

One of the basic premises put forth by the quantity theory of money (QTM) as outlined in Friedman and Schwartz's *A Monetary History of the United States*, is the idea that money supply is the primary determinant of price level. Applying the classical long run money neutrality principle and looking once again at the familiar Fischer form equation (1) with the premise that

[15] If they so desire, the developers can create a sector that runs on players digging up holes in the ground and then filling them up again. Keynes's outlandish suggestion can come to life in a virtual reality if it means that more players join the game.
[16] RuneScape features constant polling for its player base to decide on a variety of questions such as whether or not to bring back an entire previous version of the game to the aesthetics of certain in-game items.

velocity V is constant, it is clear that an increase in money supply M will need to be balanced out by, strictly speaking a one to one increase in prices P. Without a financial system,

$$MV = PY \quad (1)$$

or monetary fiscal policy, what kind of relationship could we expect to see between money, prices, and output? *EVE Online* provides the opportunity to test this hypothetical and provides a simplified and raw way of measuring these effects, considering there can be no talk of choices made with respect to interest rates, which feature prominently in reviews of the quantity theory.

In the virtual economy of any MMORPG, we should expect the quantity theory of money to hold as close to true as possible, provided the assumption of constant money demand (velocity). Players can create virtual currency in a number of ways that do not require a bank, unlike in the real world. If a player wants to acquire virtual currency, they always have faucets which they can use to acquire money. The majority of money creation should therefore be a direct result of production. If the developers increase the money put into the game through various faucets, such as raising the price floor for certain goods, players will find ways to make the most of the increased subsidies by purchasing more labor and time expensive goods. Additionally, if more players join the MMORPG once it starts to gain popularity because of the new content and fixes to the game, then we should see an increase in money supply and production and prices should quickly adjust accordingly. There is no central bank to stimulate output and instead it is money demand that stimulates money supply while both money supply and demand for goods impacts price fluctuation.

In *EVE Online* the perfect one to one relationship may not hold exactly at one to one because it reflects a real-world phenomenon: sticky prices. In the real world, labor unions and labor contracts have a long-term stabilization effect on prices separate from monetary policy (Canzoneri, 1980). Contracts are not a standard feature in MMORPGs, but they are available to

capsuleers[17] in *EVE Online* for auctioning off items in a different region's market, for the safe exchange of items between players, and for shipping materials across the EVE universe. Besides individual players, corporations and alliances can also contract out tasks. This means that there can be a degree of bargaining between individuals and corporations as to the prices of goods and the wages paid for services over time. Some of the busiest and safest regions of the game have higher prices and wages for contracts because of the premium placed on the convenience afforded by safety. Riskier regions offer lower prices for goods, thus allowing the possibility of arbitrage trading. These trade patterns are largely dictated by risk and free market principles whereas corporation run markets are normally only available to corporation members and can therefore feature different prices. We should therefore already expect the effect between a change in money and a change in prices and output to be less than one to one because of the sticky effects of these contracts and corporate markets within the game despite the fact that these contracts expire faster within the game than they would in the real world.

Lastly, *EVE Online*'s regional segmented market structure means that there is the possibility of a lag between a change in money, output, and prices. Players have to physically bring their harvests to a regional market, and this does not always prove to be a straightforward task. The reasons as to why there are contracts that agents can enter for the transportation of goods is that, depending on the journey, there is a substantial risk of bringing goods to market. Piracy is an aspect of the game many players take on. The patterns of trade between regional markets is something that will be discussed later on, but for now it is important to note the potential of a lag between money supply, nominal GDP[18], and prices.

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[17] The common name for *EVE Online* players.

[18] A measure of nominal GDP, based on the price of final goods sold, for the universe of *EVE* is available within the game and will be discussed in the data section.

3.3. Previous Research into Quantity Theory of Money

Even though the study of virtual economies is a relatively niche field, there has been research in the past with regards to this topic. In the aforementioned study of another MMORPG, *EverQuest II*, Castronova's research team found that an increase in the money supply was associated with an increase in prices over a four-month time period while the price moved inversely with the change in population (2009, p. 669). The research team was able to use all available 314 million transactions during this period to create baskets of goods, create an analogous measure of GDP, and observe the changes with respect to money supply and population. Within their data, despite high inflation, high fluctuations of nominal GDP and money supply, they found the predictions of the quantity theory of money to be consistent within the virtual world for the four-month period. Price level and nominal output moved in the same direction within the observed time frame. Although they did not conduct regressions to see the how close the empirical relationship was to the theorized one to one, the researchers' conclusion suggested the robust nature of the quantity theory of money given the unordinary fluctuations within the dataset.

A more recent experimental study which examined the effects of a money supply increase on the demand for money also supported the predictive power of the quantity theory. Researchers from the University of Niš in Serbia created an A/B controlled experiment with 575,000 subjects over twenty-eight days in the virtual football management game Top Eleven to see the effect of an increase in the endowments of a virtual currency on the demand for the currency in the short and long run (Živić et al., 2017). The experiment was created by making two different shards[19] in which players in one were given a bigger starting virtual currency endowment[20] than in the other.

[19] Clone versions of the game.
[20] Many games offer their newcomers a virtual endowment. Top11 is not an MMORPG but giving a starting endowment in this case is similar to an MMORPG.

A greater starting endowment was shown to create a greater demand for currency in the long run after the initial lowering of money demand in the short run. The researchers concluded that a positive change in the money supply in a virtual context leads to inflation and increased money demand in a much faster time frame than in real-world economies. The main caveat with this study is that the virtual economy in question is not an MMORPG, but nevertheless the experiment suggests that virtual economies should not behave differently from the real world with the exception of a faster price stabilization.

The greatest improvement that can be made to these previous studies is undertaking a larger time-period of observation. *EVE Online* allows us to see if these same findings can be replicated in another MMORPG and if they can be found over a longer period of time. For some time now, CCP games has been publishing a monthly economic report for *EVE Online* which contains various measures of the macroeconomic indicators within the game's economy. This report includes a file with a day by day measure of money supply starting from March 2012, and a monthly measure of change in CPI starting from November 2003, a couple of months after the release of the game itself. From the file containing changes of CPI, a snapshot of which is shown in figure 3.1, it is possible to work back to obtain prices and output for a given month.

period	indexName	subIndex	priceChange	totalValue	priceChangeWeighted
11/1/03	Consumer Price Index	Ammo	0.99793	5621395924	-0.000048
11/1/03	Consumer Price Index	Commodity	0.967794	1209761930	-0.000163
11/1/03	Consumer Price Index	Drones	1.026328	1391691867	0.000153
11/1/03	Consumer Price Index	Implants	0.641805	24814225220	-0.037262
11/1/03	Consumer Price Index	Skills	1.002347	40736787396	0.0004
11/1/03	Consumer Price Index	Starbase structures	1.016469	35952964597	0.002482
11/1/03	Consumer Price Index	Tech I modules	0.994753	17243435341	-0.000379
11/1/03	Consumer Price Index	Tech I ships	1.009651	1.06932E+11	0.004326
11/1/03	Consumer Price Index	Tech II modules	0.130387	4628151162	-0.016872
11/1/03	Mineral Price Index	High-End Minerals	1.054418	79317234301	0.017336
11/1/03	Mineral Price Index	Low-End Minerals	0.997431	1.69647E+11	-0.00175
11/1/03	Primary Producer Price Index	Ore	0.994527	24670427964	-0.003873
11/1/03	Primary Producer Price Index	Planetary Processed Materials	0.982903	2766366473	-0.001356
11/1/03	Primary Producer Price Index	Planetary Refined Commodities	0.990954	4998295223	-0.001297
11/1/03	Primary Producer Price Index	Planetary Specialized Commodities	1.002829	2424353653	0.000196
11/1/03	Secondary Producer Price Index	Blueprints	1.007883	40697636435	0.000777
11/1/03	Secondary Producer Price Index	Commodity	0.993285	1.1431E+11	-0.001861
11/1/03	Secondary Producer Price Index	Planetary Commodities	0.956725	342931274.6	-0.000035
11/1/03	Secondary Producer Price Index	Planetary Refined Commodities	0.923383	13295629159	-0.002469
11/1/03	Secondary Producer Price Index	Planetary Specialized Commodities	1.007038	2.43774E+11	0.00416

Figure 3.1: A snapshot of the Economic Indices Excel file download ("Monthly Economic Report - March 2020" | EVE Online, n.d.)

3.4. Data Creation and Overview

The first step in recreating the full economic picture, is to reaggregate CPI over the different listed sub-indexes. The key assumption here is that the 'totalValue' cell represents the total nominal output of a certain sub index produced over the given month and the 'priceChange' represents the change in price of the basket over the given month. Let j stand for a given sub index and let t stand for a given month, then the change in price level, P for any given time can be calculated as:

(2) $$\Delta P_t = \sum_j \log\left(\Delta P_t^j\right) \frac{\Delta P_{t-1}^j \Delta Q_{t-1}^j}{\sum_j \Delta P_{t-1}^j \Delta Q_{t-1}^j}$$

The price change in any time period is weighted with respect to the previous time period. Taking the natural log of the change in prices allows us to later measure changes in percent since we are interested in the effects of a growth in money supply on prices and output. The price level is then calculated for every period t by taking the cumulative sum of the changes in price up until t:

(3) $$P_t = \sum_{t=1}^{t} \Delta P_t$$

Thus, a data set was generated through Python and R. 197 values for price level, and output as a measure of nominal GDP were each were created over the time period of November 2003 to March 2020. A separate excel file containing money supply was used to collect the corresponding supply for the day and month of each price and output measure. Unfortunately, the recording of total in-game money supply only goes back to March 2012, so only ninety-seven months were available for measuring the effects of changes in money supply. Furthermore, velocity at any time t for these ninety-seven months was estimated by rearranging the Fischer equation shown in equation 4.

(4) $$V = \frac{PY}{M} = \frac{\sum_j \Delta P_t^j \Delta Q_t^j}{M}$$

Before conducting regression analysis, velocity was observed over this time period to see if the game exhibits a constant money demand. The graph generated is displayed in figure 3.2. This graph includes the periods in which major expansions were announced and then released, the significance of which will be discussed in the next section. Looking at figure 3.2, we can see that although our estimate of money demand has periods of variation, the most significant of these are

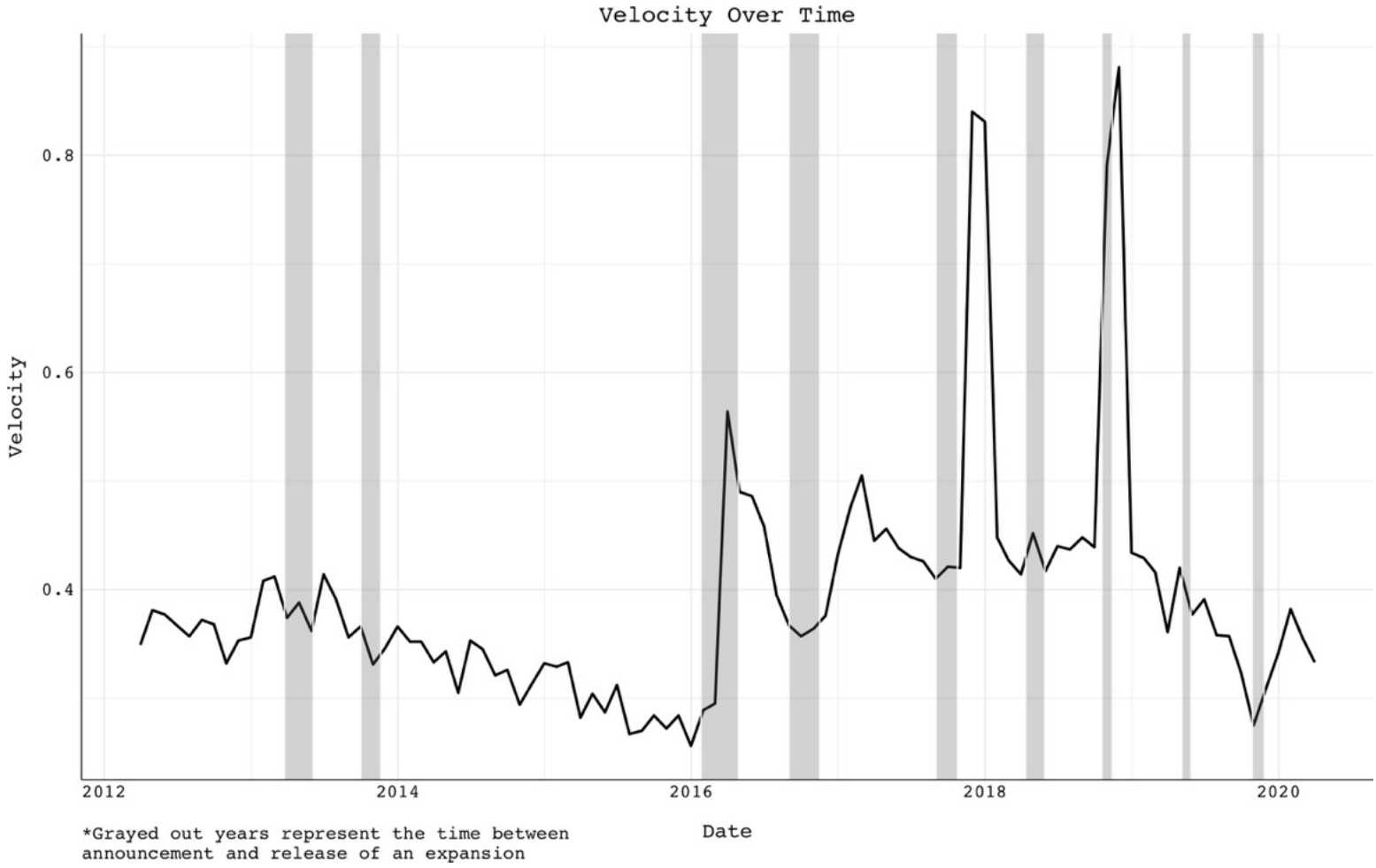

Figure 3.2: Velocity Over Time as estimated by output and money supply

due either to the lead up of a major expansion or as a result of a major expansion. Besides the huge spikes, we can see that there is an overall downward trend in money demand over time. The graphs of velocity provided by CCP games in their monthly economic report record less fluctuations but similar and smoother changes in money demand. The only sudden spike that carries over from the graph generated by me to CCP's graph is the one around 2016, where the definition of active player count was changed. I took the measures of velocity provided by the publishers to be more accurate, as they likely derive it from the actual amount of currency exchanged in trade, which I do not have access to, and the amount of money destroyed in currency sinks. The reason for the overall decrease in velocity, I believe, is due to the overall slow descent in player count during this time period, as shown in figure 3.3. Less players means that less ISK is changing hands, given all else, in this case the growth of money supply, held equal. Since the descent of money demand is spread over long enough periods of time, and because huge spikes in velocity happen rarely, I will take money demand as constant when regressing money supply on price and nominal output.

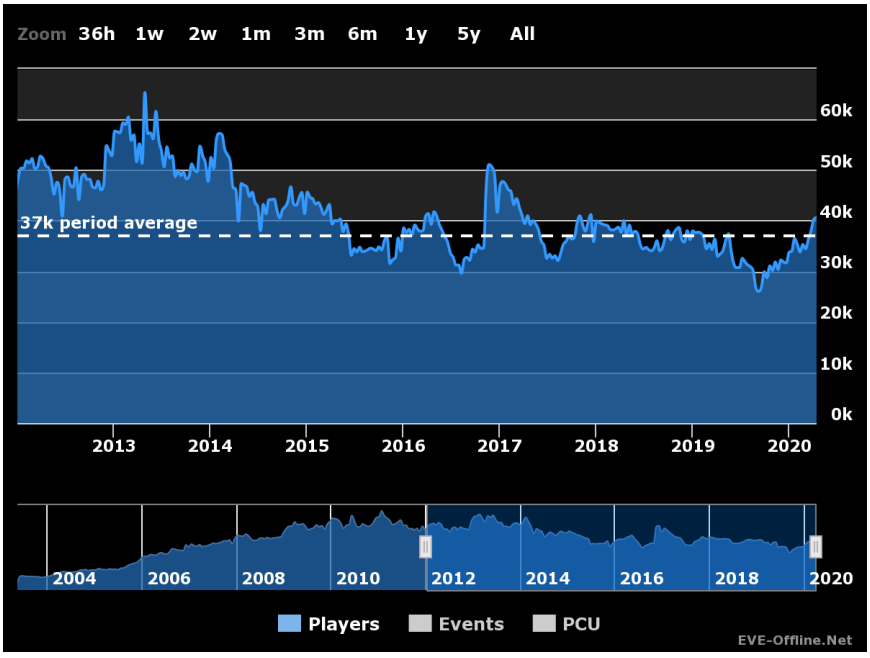

Figure 3.3: A snapshot of concurrent player count over time (EVE-Online Status monitor" | EVE-Offline.net, n.d.)

3.5. Model and Regression Results

To capture the relationship between money supply and nominal output, the log of both sides of equation (1) was taken and because there is no change in velocity, we get the functional

(5) $$\ln(PY) = \ln(M) + \ln(V)$$

form in equation (6). The results of regressing money on nominal output is shown in figure 3.4

(6) $$\ln(PY) = \beta_0 + \beta_1 \ln(M)$$

and table 3.1 below. The results of table 3.1 below show that a one percent increase in money supply is associated with, on average, a 1.254% increase in nominal output. The positive sign and

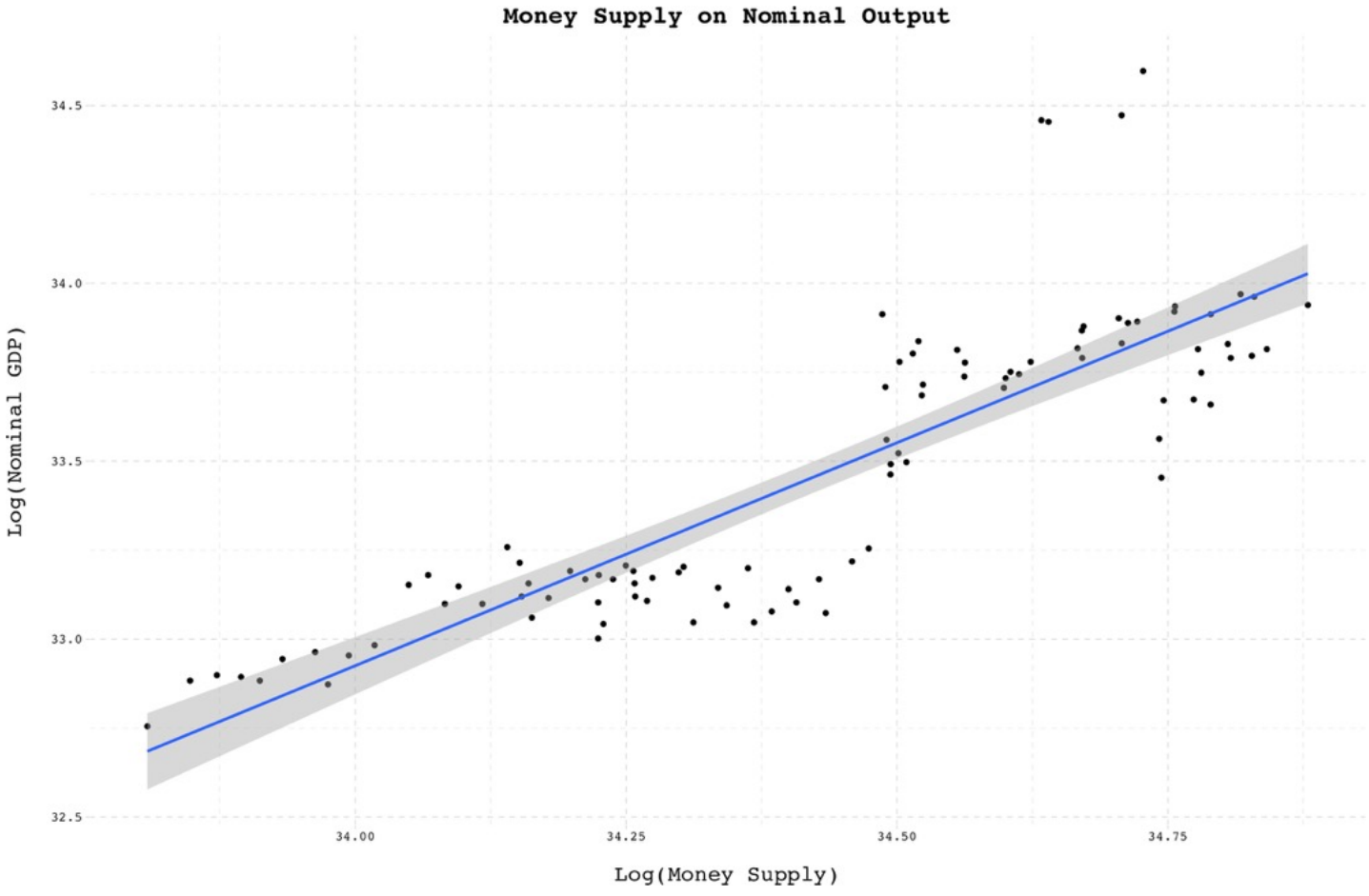

Figure 3.4: Money Supply vs Nominal Output

Table 3.1: QTM on Output/Nominal GDP

	Dependent Variable
	ln(Output)
ln(Money Supply)	1.254 ***
	(0.079)
Intercept	-9.696***
	(2.734)
N	97
R^2	0.724
Adj.R^2	0.721
F-Statistic	249.171***
	(df=1; 95)

*** p < 0.001; ** p < 0.01; * p < 0.05

highly significant coefficient are consistent with the predictions of the quantity theory, although the effect should be closer to a one to one relationship. We will discuss the implications of a greater than a one to one effect in the next section.

Observing the relationship between money supply and prices proved to be more complicated. Figure 3.5 puts nominal output, prices, and money supply together for comparison over this six year time period while table 3.2 displays the two different models that were applied to understand the effect of money supply on prices. Table 3.2 is also accompanied by a graphical representation of the second model, which has an interaction and intervention term: expansion. The expansion variable captures the before and aftereffects of the *Ascension* expansion to *EVE Online*; the details of this expansion and the reason for the inclusion of this intervention variable are outlined in the subsequent section.

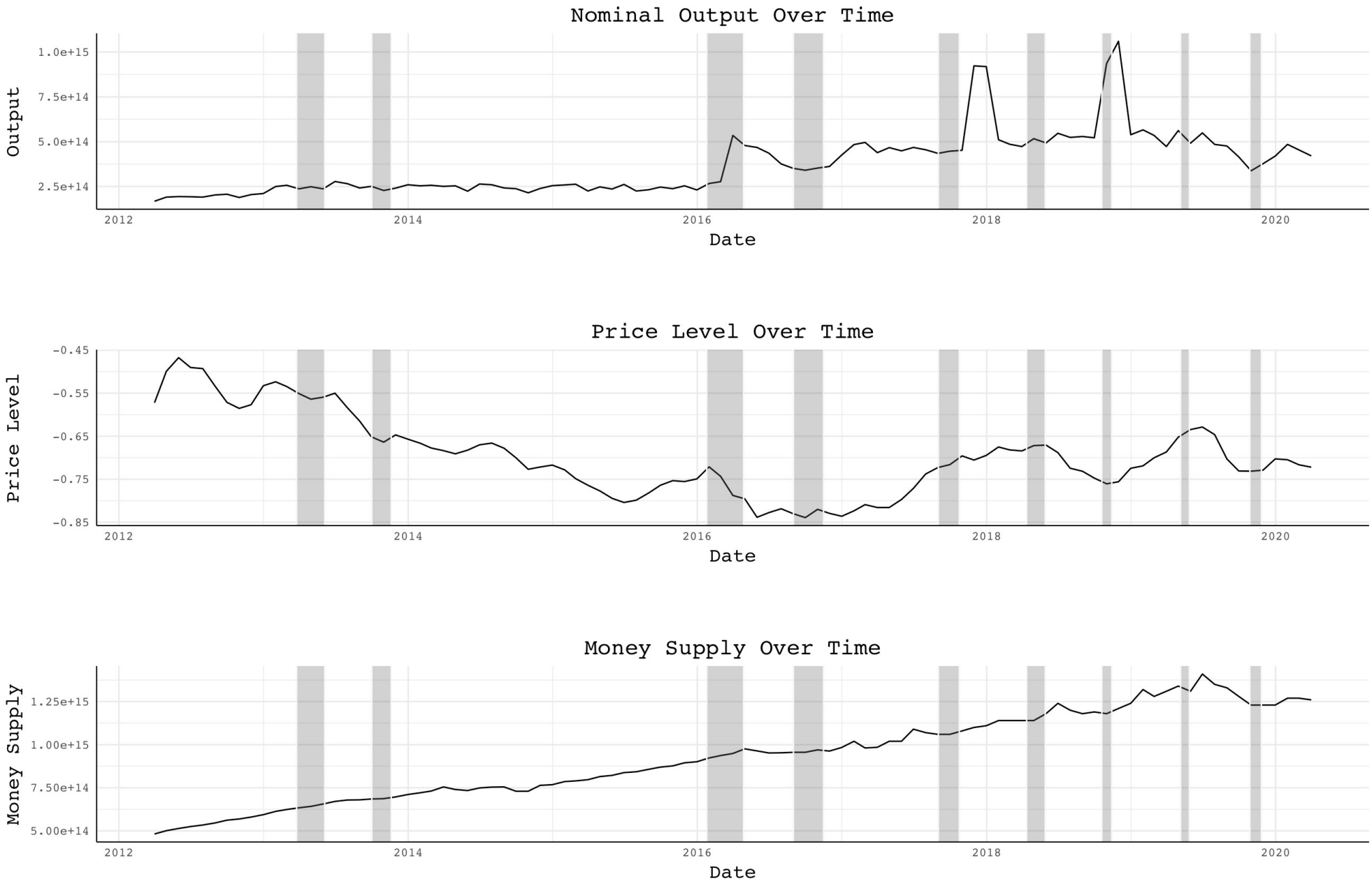

Figure 3.5: Money Supply, Prices, and Nominal Output

Table 3.2: QTM on Prices with Content Expansion

	Dependent Variable: Price	
	Model 1	Model 2
ln(Money Supply)	-0.187***	-0.515***
	(0.027)	(0.026)
Post-Expansion		-31.172 ***
		(2.212)
Post Expansion x ln(Money Supply)		0.904***
		(0.064)
Intercept	5.753***	16.960***
	(0.935)	(0.895)
N	97	97
R^2	0.334	0.835
Adj.R^2	0.327	0.829
F-Statistic	47.579***	156.509***
	(df=1;95)	(df=3;93)

*** p < 0.001; ** p < 0.01; * p < 0.05

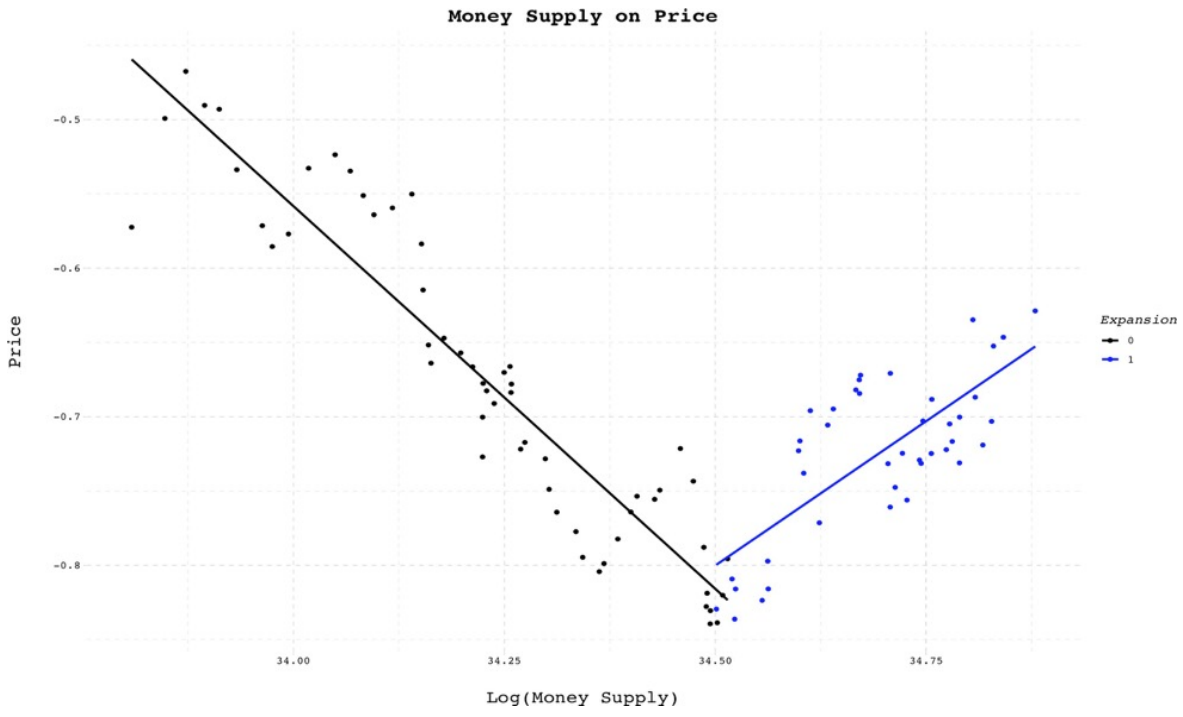

Figure 3.6: Money Supply and Prices, with Expansion Interaction

Models 1 and 2, whose functional form is outlined in equations 7 and 8, reveal that although the overall relationship between money supply and prices is negative and relatively close to zero, the effect of money supply has recently, as of 2016, been positive, although still closer to zero than

$$\ln(P) = \beta_0 + \beta_1 \ln(M) \tag{7}$$

$$\ln(P) = \beta_0 + \beta_1 \ln(M) + \beta_2 Expansion + \beta_3 [\ln(M) * Expansion] \tag{8}$$

to a one to one effect. We can see from figure 3.6 that price levels have been falling over time within the *EVE* economy; this trend is noticed by players as well on online forums and discussions about the state of the deflationary economy. In fact, deflation is observed by the developers of the game themselves in both old economic newsletters from 2007[21] and their current monthly reports which include the developer's measure of CPI. The expansion variable shows more or less the turning point, at least as of late, of the deflationary trend. After November 11th 2016, a 1% growth in money supply on the effect of prices, on average, is associated with a total .389% increase in price level. This leads us to ask why nominal output increases with money supply growth while prices fall? This contradiction and opposition to the quantity theory can be explained with the business cycle.

3.6. Real Business Cycle (RBC), QTM, and EVE Online

Bringing together the notions of unemployment, government market intervention, and creation of money in *EVE* leads us to consider the way in which the neo-classical model of the business cycle determines prices and output. The real business cycle is directly applicable here

[21] CCP Games used to publish an economic news letter quarterly which had a lot of in-depth information and defined many of the same terms defined in this paper. For the quarterly letter, see:
Guðmundsson, E. and Halldórsson, K.Þ., (2007). Quarterly Economic Newsletter. *Available at* URL<http://www.nytimes.com/packages/pdf/arts/QEN.pdf>

because, as stated by Prescott, the cycle is described by fluctuations in "output and unemployment about trend" where "two-thirds of business cycle fluctuations are accounted for by variations in the labor input, one-third by variations in total factor productivity, and virtually zero by variations in the capital service input" (2006). Considering there is no capital service input in *EVE*, due to the lack of a finance sector, we can say that the business cycle model should be a dominant determinant of the changes in prices within the virtual economy.

The movement of the economy along the business cycle, as well as the subsequent movement in prices within, depends solely on 'inside money' in both the real world and *EVE Online*. King and Plosser define inside money as the amount of money deposits currently available (1984); to the players in *EVE* there is only inside money, or the currency already existing (deposited by faucets) in the game. It is possible to exchange real currency for in-game currency[22], ISK, but I am assuming that the majority or ISK creation is through in-game activities. King and Plosser find that "much of the contemporaneous correlation of economic activity and money is apparently with inside money with inflation principally resulting from changes in the stock of fiat (or outside) money and variations in real activity" (1984, p. 378). This is due to the fact that, within the real business cycle model, "a positive correlation (comovement) of real production, credit, and transaction services arises from the general equilibrium of production and consumption decisions by firms and households" where "the timing patterns among these variables…depends on the source of the variation in real output" (King and Plosser, 1984). This ties in perfectly with the situation presented in *EVE Online*.

[22] PLEX is a sort of medium of exchange in EVE that can allow players to essentially purchase ISK with USD. It is also possible to pay third-parties for the procurement of virtual currency with payment of real currency. It is hard to tell how often either of these services are used within the game.

The cyclical economy of *EVE Online* fluctuates with the decisions made by developers in regard to the timing and the content of their in-game expansions, which are more often than not, analogous to technology shocks. Kydland and Prescott first introduced technology shocks as an explanatory variable for business cycle fluctuations in their 1982 paper. It has since been presented in different forms but within a sticky price model, like that in *EVE*'s contract based marketplace, Gali finds that "a monetary shock has a transitory impact on output employment, and productivity, and a permanent effect on the price level" while "a (positive) technology shock has a permanent, one-for-one effect on output and productivity… a permanent negative effect on the price level as long as…the degree of monetary accommodation is not too strong" (1999, page 253). CCP games has constantly added expansions to *EVE Online*, with the current rate of content addition being roughly two major expansions per year, once in the fall and spring although it was more frequent in the past. The addition of new content works in part to attract new users (decreasing unemployment in a sense) and retain the current player base. These expansions change, to varying degrees, the ways in which production takes place in the game and often the new methods of production create more efficient ways to allocate resources for the production of major goods. Individuals, but more importantly, corporations, take advantage of these new production methods and prices fall as a result of efficient production. The more players that join the game, the further the price falls. It also becomes harder for new 'firms', in this case individuals or small corporations, to engage with markets because it becomes more time consuming to generate the same amount of wealth as before. Additionally, existing corporations and current players are able to prepare for expansions more effectively than the newer players these changes to the game are meant to bring in, further crowding out the markets. Players leave the game, but prices do not recover as corporations become more efficient at production for their own consumption and they no longer

seek to create more inside money. The result is that nominal output increases throughout the expansions as real output increases faster than prices fall. If the USD to ISK exchange rate, made possible through purchasing PLEX (detailed in the next paragraph), were lowered, it would be easier for new players to enter and raise demand for goods, and therefore prices, as they seek to start their own corporations and trade. Figure 3.7 on the next page offers a comparison between logged output, price level, and population count shown by figure 3.8 spanning 197 months or nearly the entire lifetime of the game.

If more players don't join, CCP games will need another strategy to raise prices in the virtual world, if they see them as an issue at all, and this approach is reflected in the November 16th, 2016 update, *Ascension*. This expansion to the game introduced an alpha and omega state of the game where the omega state is available for players to enjoy without paying a monthly subscription, something that players have had to do hitherto. The omega state of the game features less of the content that would be available in the alpha state. Players who enjoy the free version, may upgrade in one of two ways: either the omega players buy the aforementioned PLEX with real world money, which can be exchanged for hours of gameplay in the alpha state, or they can buy a monthly subscription. Even if the newer players in the omega state do not end up buying the full version of the game, they are still helpful since they will need to produce inside money in order to purchase the goods they need within the game to get started. More expansions to the game such as this could help raise prices, as seen in the predicted effects on an increase in money supply on prices post *Ascension*.

The next steps for researching macroeconomic trends within *EVE Online* would be to collect better data of active player count over time. Fluctuations in populations within the game occurred more rapidly than they would be observed within the real world. The MMORPG would

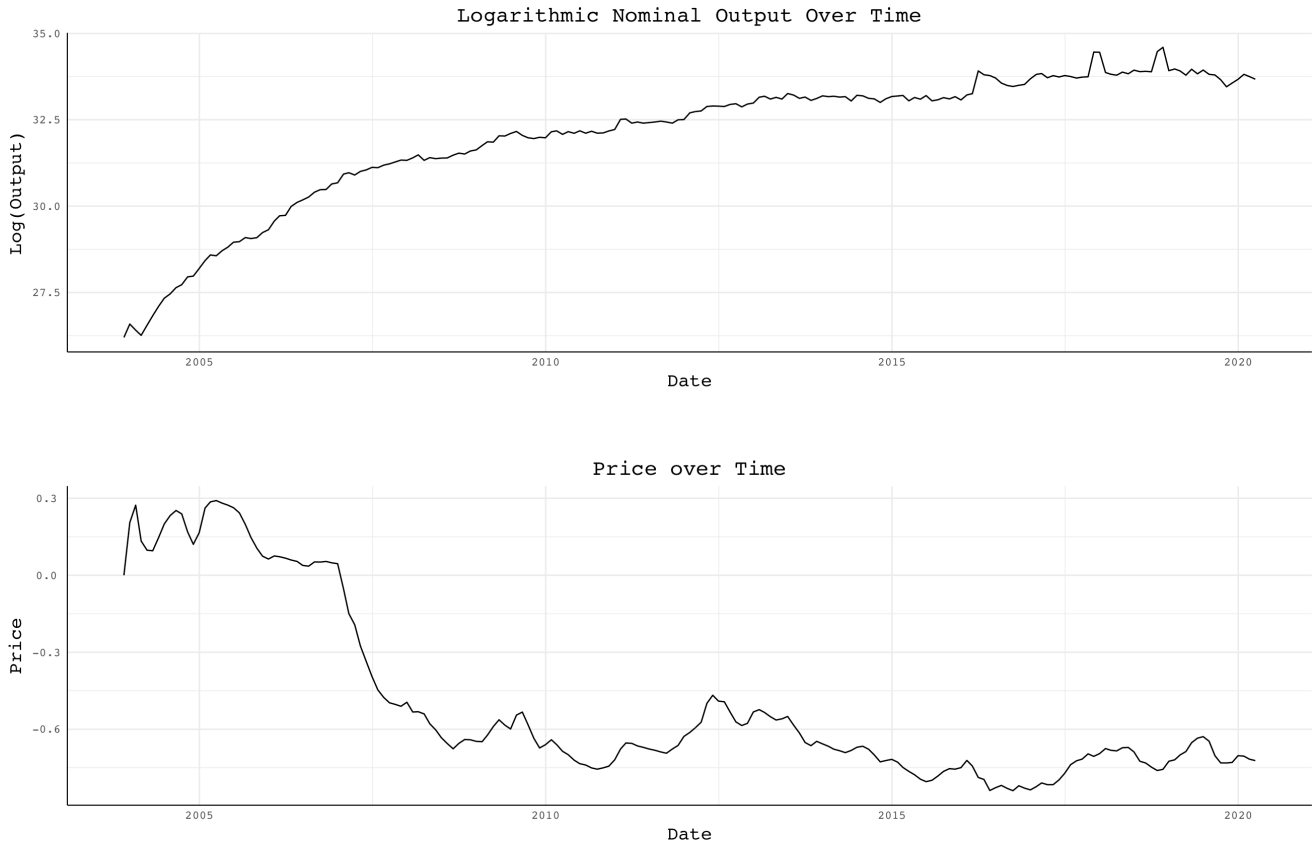

Figure 3.7: Logarithmic Output and Prices Over time

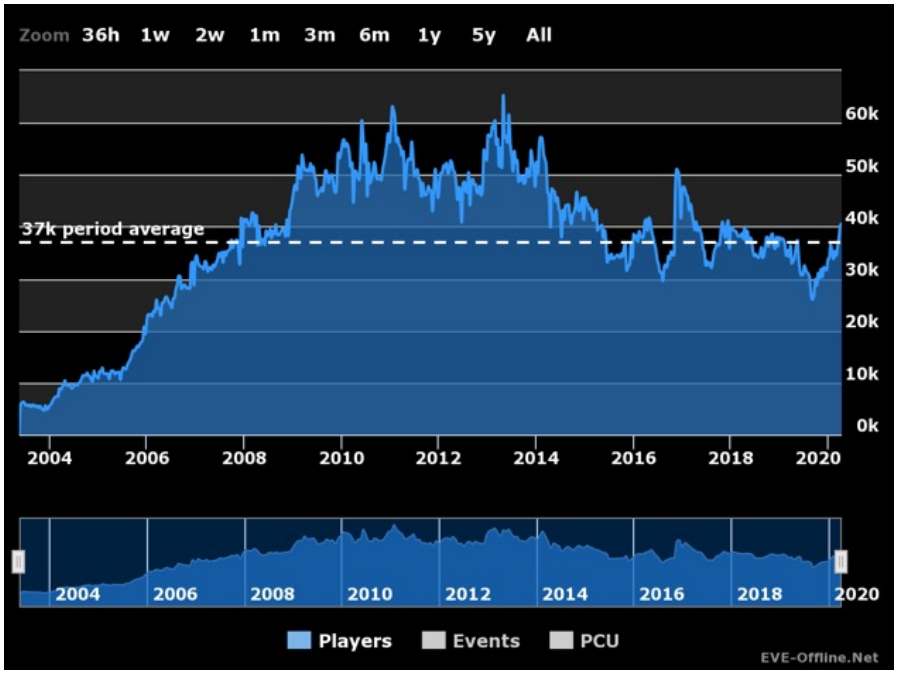

Figure 3.8: A snapshot of concurrent player count over time ("EVE-Online Status monitor" | EVE-Offline.net, n.d.)

provide an interesting case study as to the effects that sharp population change has on prices within an economy. This presents an opportunity to further study something that could only be theorized up until the development of the virtual world and the virtual economies therein.

4. Gravity Model of Trade

4.1. Gravity Model Theory and EVE

Given the available data on distances between regions and net exports by region for sixty-four regions over the course of around 46 months, I further explored the research potential of MMORPGs by testing if the pattern of trade across regions follows that which would be predicted by the Gravity Model of Trade. This exploration within *EVE Online* is worthwhile because it features barriers to trade similar to that of the real world without the advancements made to lower these barriers. The *EVE* universe serves as a counterfactual in this sense to the global economy since it lacks notions of tariffs or free trade agreements while still retaining analogous sovereign boundaries and piracy.

The Gravity Model Theory of trade has been a powerful yet simple tool in the study of international trade. Borrowing and reworking the equation for gravity from physics, the main equation stipulates that: "A mass of goods or labor or other factors of production supplied at origin i, Y_i is attracted to a mass of demand for goods or labor at destination j, E_j, but the potential flow is reduced by the distance between them, d_{ij}" expressed in equation 9 (Anderson, 2011, page 135).

(9) $$X_{ij} = \frac{Y_i E_j}{d_{ij}^2}$$

A world without frictions would lead to equation 10 where among disaggregated goods, indexed

(10) $$X_{ij}^{k} = \frac{Y_i^k E_j^k}{Y^k} = s_j^k b_j^k Y^k$$

by k, the trade flows of any country are given by $s_j^k = {Y_i^k}/{Y^k}$, which is country i's share of the world's sale of goods class k, $b_j^k = {E_i^k}/{Y^k}$, which is country j's share of the world's spending on k, equal to Y^k, the world's sales of k (Anderson, 2011, page 136). The implication of interest for this paper drawn from equation 10 is that small sellers would be more open to trading with the rest of the world since only data on net exports by region in *EVE Online* is available.

In EVE Online the main boundaries to this frictionless world would presumably be sovereign corporations and piracy. The central regions of the game are owned by NPCs, where all players can trade with the reasonable expectation that they will not be attacked when doing so because of the high security measure within this region.[23] Security within any given space is given as a measure from -1 to 1 in increments of 0.1 and each player has their own security status, which usually ranges between -5.0 to 5.0, that indicates whether or not they are an 'outlaw' depending on their past actions. If a player is to attack another merchant in the high security measure regions, they will drop to an outlaw status and can expect a quick retaliation from powerful NPC security that quickly shows up to neutralize the aggressive party. Regions with lower levels of security have trading hubs that are riskier because NPC security guards will not arrive, and only passive sentry guns maintain a form of law. Regions with a security level of 0 or below – this space is referred to as 'nullsec' by players – offer no form of protection against outlaws and no prohibitions on the weapons that can be used. Within these outer regions corporations can claim sovereignty over a region and set up their own trading hubs. Most of the corporate run trading hubs are

[23] Quick raids by corporations against one another have taken place in high security regions although this is the exception and not the norm.

available only to corporation members, but even then, they cannot guarantee the security of members within this region as a corporate run border control, if it exists, may not always catch every intruder. Every day the sovereignty claims made by corporations within nullsec star systems is subject to change as a result of either warfare or diplomacy.

4.2. Trade Openness and Regression Results

Using the available net exports by region, production by region, average distance from the trading hub in the center of the map (in AU[24]), and whether or not each region had an average security rating higher than 0, I measured whether or not the smaller producing regions were more open to trade with the rest of the universe than the bigger producing regions. Trade openness by region is defined by equation 11 below. The expectation is that neither distance or measure of security impedes on the relationship proposed by the frictionless model which suggests that the

$$Openness = \frac{Nominal\ Imports + Nominal\ Exports}{Nominal\ Output} = \frac{I + E}{PY} \tag{11}$$

less productive regions to have a greater measure of openness than more producing regions. In other words, I expected nominal output to have a negative effect on the openness measure. It is important to note that the measure of net exports also includes the movement of capital ships. If expensive ships left a region, they increased the nominal amount exported and if expensive ships entered a region, then they increased the nominal amount imported. In a limited sense, the measure of openness will thus also account for labor migration.

The results in Table 4.1 show four different models which were created. Figure 4.1 displays model 1, which is the relationship between production and distance without any other variables,

[24] Astronomical Units, the standard measure of distances in space in our universe and in the EVE universe.

Table 4.1: Production, Distance, and Nullsec[a] on Openness

	Dependent Variable: ln(Openness)		
	Model 1	Model 2	Model 3
ln(Nominal Regional Production)	-0.366***	-0.414***	-0.410***
	(0.024)	(0.025)	(0.025)
ln(Distance)		-0.377***	0.134
		(0.049)	(0.054)
Nullsec			-0.808***
			(0.118)
Nullsec*ln(Distance)			-0.000017
			(0.00006)
Intercept	13.377***	17.425***	14.379***
	(0.664)	(0.843)	(1.056)
N	3062	3062	3062
R^2	0.071	0.088	0.135
Adj.R^2	0.070	0.088	0.134
F-Statistic	232.968***	148.222***	119.018***
	(df=1;3060)	(df=2;3059)	(df=3,3057)

*** p < 0.001; ** p < 0.01; * p < 0.05

a. Nullsec is an indicator variable which is 1 if the average security rating of a regions is 0 or less.

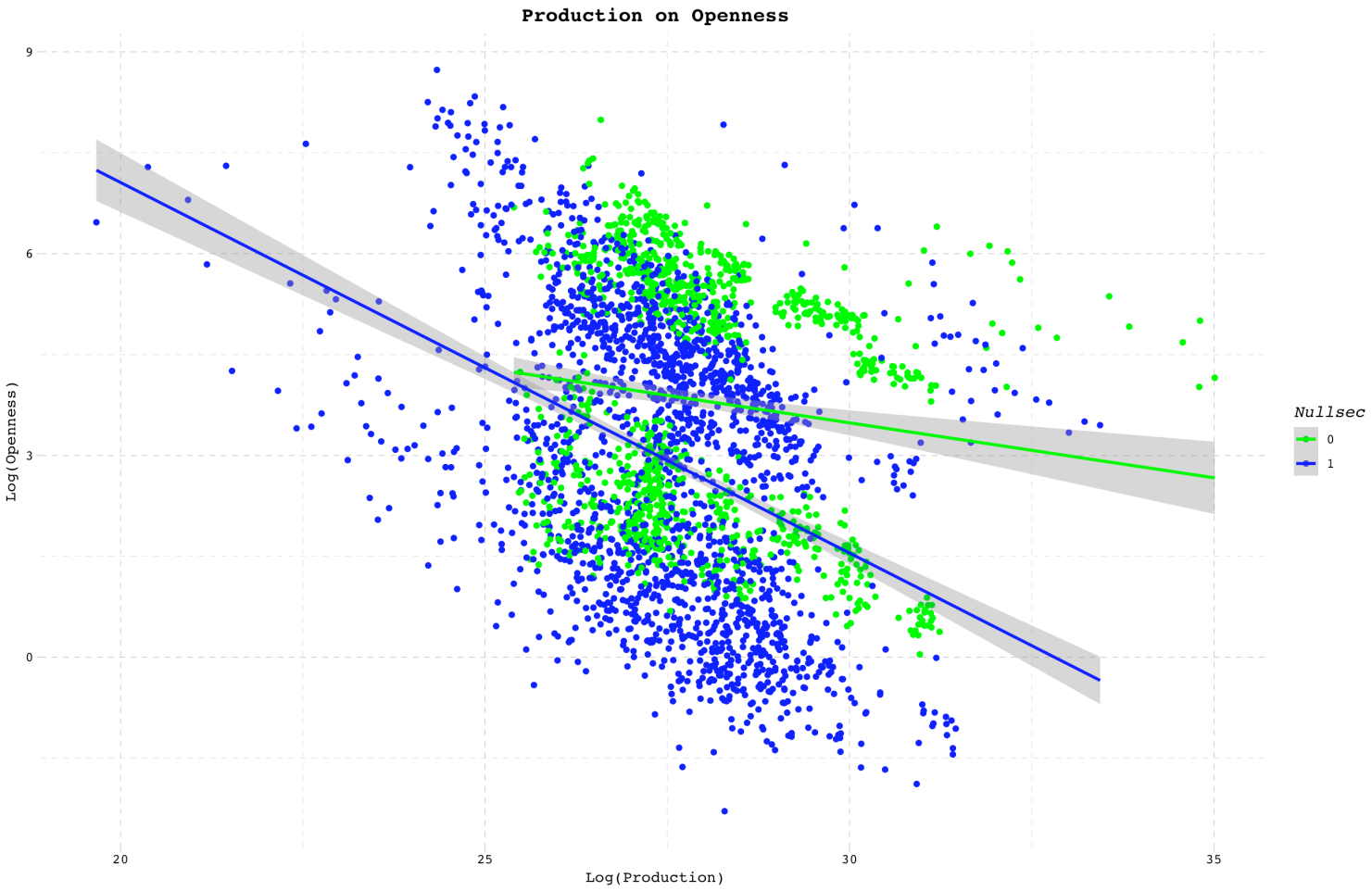

Figure 4.1: Logarithmic production versus logarithmic openness by Nullsec categorization

in logarithmic form varied on nullsec. Nullsec indicates whether or not a region has an average security rating that is less than 0. As expected, regional output overall has a negative relationship with the created measure of openness and this persists across all four models. The most surprising result comes when comparing models 2, and 3. Once our measure of security is introduced, it becomes a more important predictor of openness than the distance of that region from Jita, the central trading hub of the universe. Model 3 accounts for the interaction between distance and

whether the average regional security measure is less than 0. The functional form of model 4 is given in equation 12:

$$\ln(Openness) = \beta_0 + B_1 \ln(Nominal\ Regional\ Production) + B_2 \ln(Distance) + B_3 Nullsec + B_4[\ln(Distance) * Nullsec] \quad (12)$$

Model 3 shows by proxy the effect that sovereignty borders have on the patterns of trade within the *EVE* universe. If a region is nullsec, it more than likely has a corporation claiming sovereignty of some or all of the region's star systems and therefore we see a negative effect on openness as a result. This effect carries over to distance as shown by the negative sign of the interaction term although the interaction term is not significant in the model. Overall, if a region is nullsec, then it has about a 0.8% decrease on the openness of that region.

There remains much unexplained variation in openness over the 46 month period but these simple regressive results have powerful implications. This is largely because bilateral trade information was not used since it was unavailable to be accessed. Different regions may have different degrees of trade with respect to the central trading hub which is where the effect of distance stems from. Nullsec regions may be more open to trade with higher security regions closer to them, although these higher security regions are themselves are quite a distance away from Jita.

4.3. Connections to Real World Observations

The relationship observed between borders, distance, and trade in EVE Online have strong parallels to the discussion of these topics within real world cross-country or cross-border trading patterns. Balistreri and Hillberry's review of Anderson's border puzzle showed that even with adjustments made to the measurement of cross-border trade at one of the most lenient boundaries, the US-Canadian one, there is still a significant decrease in trade with the presence of a border

(2007). This border still has as much of an effect in deterring trade as if the countries were 1,500 and 2,500 miles apart (Howard, 2000). We can see from a map of the corporate sovereignty claimed within nullsec on April 26th, 2020 in figure 4.3 that there is a similar effect of borders

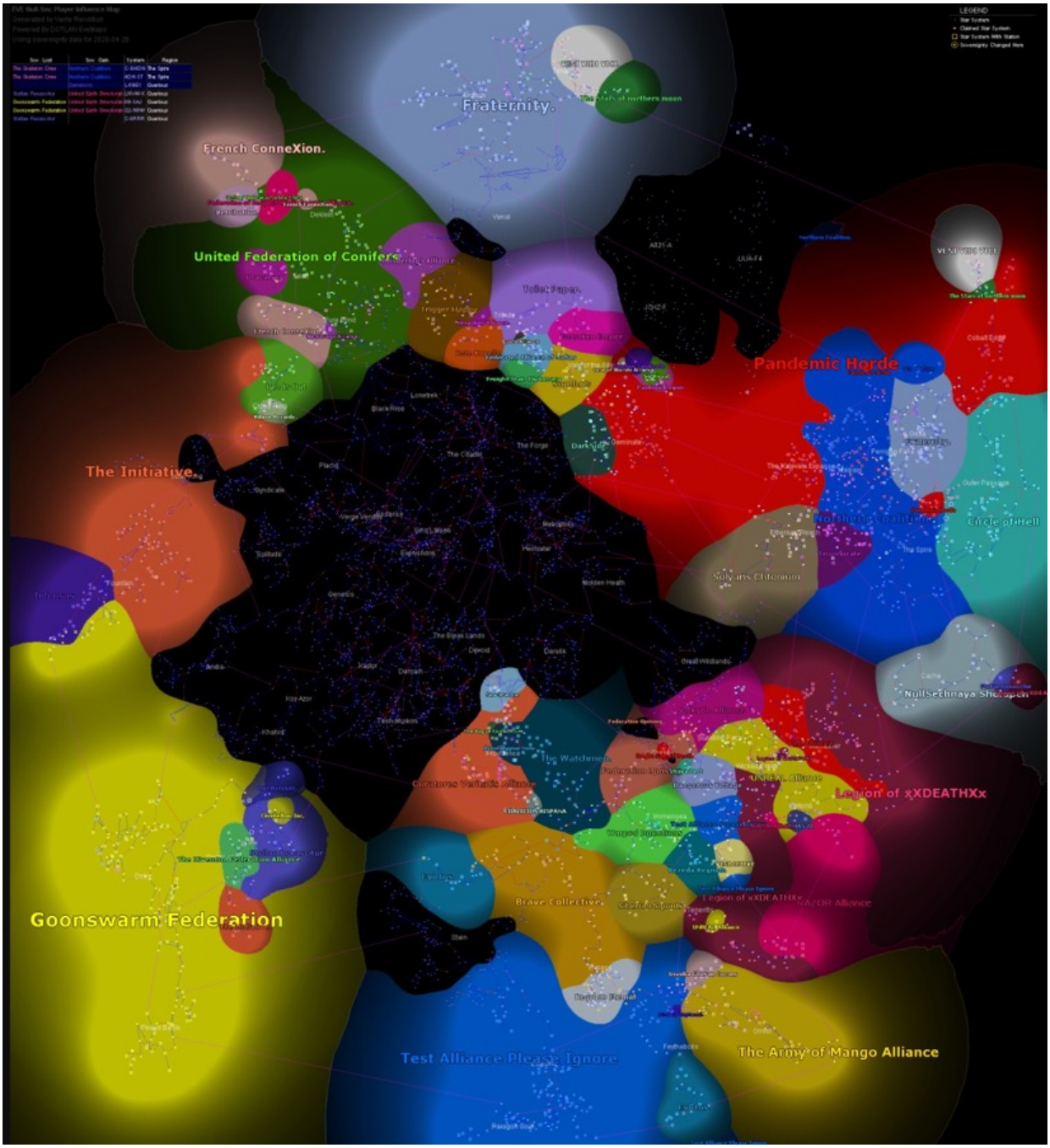

Figure 4.3: A snapshot of corporate sovereignty claims ("EVE-Online Daily Sov Maps" | sov.space, n.d.)

within the game from the standpoint of overall trade relative to the center of the universe. Some of the borders set up by corporations are closer to Jita than others and yet the overall effect of the nullsec variable indicates that these bordered regions are still less likely to be open to trade as those unclaimable, higher security regions which are further away from the central trading hub. One of the reasons for this observation within the real world is believed to be the existence of separate national currencies which can still remain an impediment to international trade (Krugman, Obstfeld, and Melitz, 2011, p. 15). The reasons for the prominent effects of borders are still not fully understood, but perhaps *EVE* gives a suggestion of where to look.

This simple study of *EVE Online*'s trading patterns implies that property rights to trade should be an important variable to include within adjustments to friction within the gravity model of trade. The implications could also extend to disciplines closely related to economics. For instance, the conflict-trade model with geographic distance within International Studies may be endogenous; it is certainly possible that while trade predicts interstate conflict likelihood, conflict impacts interstate trade to a significant extent (Chang, Polachek, and Robst, 2004). Although there is a greater profit to be made running between the risker regions of *EVE*, it seems as though it is a risk few are willing to take with or without the protection of a corporation. The next steps in observing the relationship between property protection, distance, and trade would be with bilateral measures of trade between regions in *EVE*; it may still be the case that regions closer to one another trade more frequently despite the existence of borders.

5. Conclusion

The aim of this paper was to show the merits of MMORPG's virtual economies for macroeconomic research, and I believe that the study of the money, prices, output, and trading

patterns within *EVE Online* has provided convincing evidence for this argument. For the quantity theory of money discussion, we can see that MMORPGs can offer a variety of unique environments for appraising general theories on economic growth. *EVE* shows that something as complex as the business cycle can fit within a virtual economy. The comparison between this study and Castonova's observations of *EverQuest II* mimics conversations had between economists on views held regarding the use and effectiveness of monetary policy. A generalized version of the gravity model within *EVE* also follows a sequence of research similar to that in economic journals where frictional adjustments to the model are discussed. All the while, *EVE Online* features no financial sector and segmented markets but at the same time has large firms and currency exchange with the real world. The aforementioned *RuneScape* in section 3.1 is an MMORPG that features efficient markets and no costs for brining goods to market but also a noticeable amount of third-party currency exchange. *World of Warcraft* mentioned in the introduction also has a significant amount of third-party currency exchange but segmented markets. No two MMORPGs are exactly alike, and each one has the potential for the future testing of different macroeconomic hypotheses.

6. Acknowledgements

Many thanks to Professor Ryan Chahrour for his patience and willingness to explore the field of virtual economics with me. It is not easy to create analogies in macroeconomics for everything observed within MMORPGs and without his guidance

I would not have been able to take the study to such an interesting direction. I would also like to thank Professor Robert Murphy and the Economics Department for the opportunity to write

my thesis and for being able to have fun with it by studying something that's a little more out of the box.

Finally, I'd like to thank my family, friends, and previous faculty I have studied under. Whether it be moral or academic support I couldn't do it without the people that have helped me get to this point in time.

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